Hidden Teacher Effort in Educational Production: Monitoring vs. Merit Pay

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Abstract

This paper deals with the optimality of teacher incentive contracts in the presence of costly or limited government resources. It considers educational production under asymmetric information as a function of teacher effort and class size. In the presence of costly government resources and convex effort costs, teacher monitoring – which is wasteful in principle – may be superior to merit pay in order to induce second-best teacher effort; optimum class size is not affected by informational deficiencies. If the government budget is exogenously fixed, optimum teacher effort may not be affordable, which is shown to make the case for monitoring activity instead of incentive pay even stronger.

Keywords: Education, Moral Hazard, Monitoring, Merit Pay

JEL-Classification: I21, I28, D82

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1 Introduction

We consider merit pay and accountability through monitoring as alternatives to provide optimum teacher effort which is a priori unobservable. While merit pay is a priori costless to society since it consists of a pure transfer from the government to teachers, monitoring appears to be socially wasteful since it is not productive in any sense – other than its contribution to uncover possibly hidden teacher effort. Hence, there seems to be a strong case in favor of merit pay. However, practical experience shows that merit pay is very rarely employed as teacher incentive program. There is a strand of literature explaining the aversion to merit pay by the multidimensionality of teacher effort which is hard to optimally tackle via incentive contracts (cf. Holmstrom and Milgrom, 1991 on the fundamental to incentivize agents in a multitasking framework). Our model proposes another explanation: If government resources are costly, and teacher effort is not observable, the cost of teacher information rent may outweigh the cost associated with monitoring. It is shown under which conditions – concerning effort costs, student attention, resource costs and monitoring costs – monitoring is the preferred government policy from a social perspective and how the decision depends on the optimum teacher effort's interaction with class size and on the nature of the government budget constraint.

A similar approach is taken by Jost (1991) who extends the general framework of principal-agent relationships by – among others – Grossman and Hart (1993) by assuming that the principal has the possibility of monitoring the agent at some fixed cost. As opposed to the model presented in this paper, he assumes that monitoring is imperfect and used in parallel with an incentive contract to induce optimum behavior. In this setting, the principal is not able to commit himself to implementing monitoring, he is thus tempted to save the monitoring costs. In our model, this problem does not occur since we assume that the government can commit to its teacher reward and control policy. A more fundamental difference between the approach taken by Jost (1991) and ours is that Jost uses a framework where the inefficiency in the allocation under asymmetric information with hidden action is due to an inefficient allocation of risk, while in our approach, agents are risk neutral and the inefficiency results from the imposition of a limited liability constraint, protecting the agent from negative transfers.

We start by discussing dimensions of teacher motivation (section 2) and teacher incentives (section 3) before considering specific contracts in section 5.

2 Teacher Motivation

Spear, Gould, and Lee (2000) present evidence that a teaching career scores highly for undergraduates on the opportunities given for having creative input, benefiting society, and working with individuals. The most common reasons are job satisfaction and working with children. The reasons rated as least important included working hours, holidays, salaries and security. It seems that prospective teachers are principally attracted to the profession by the rewarding nature of the work involved, as opposed to the pay or conditions on offer.

It is obvious that teacher motivation and morale are of eminent importance in determining students' educational achievement. Studies analyzed by Spear, Gould, and Lee (2000) reveal that teachers believe their own morale to be largely determined by their quality of life within the school, rating factors such as good relations with pupils and helping pupils to achieve as very important. When asked to name those factors that they felt could have a positive effect on the morale of the profession as a whole, teachers' responses largely relate to factors external to the process of teaching itself, focusing on a more positive portrayal of the teaching profession by the media, increased pay and conditions and less pressure. It seems that to improve both the morale of individual teachers and the ethos of the profession as a whole, a range of measures is needed, addressing both experiences integral to the work of teaching, and factors linked to the structural and social context within which that work is carried out.

The main factor found to contribute to the job satisfaction of teachers is working with children. Additional factors included developing warm, personal relationships with pupils, the intellectual challenge of teaching as well as autonomy and independence. In contrast, teachers viewed job dissatisfaction as principally contributed to by work overload, poor pay and perceptions of how teachers are viewed by society.

In order to experience high job satisfaction, teachers need an intellectual challenge, their autonomy, to feel that they are benefiting society, to enjoy good relations with their colleagues and to spend a sufficient proportion of their time working with children. Enhanced pay, improved status, a less demanding workload and fewer administrative responsibilities should result in lower levels of job dissatisfaction among teachers, but will not necessarily bring about higher levels of job satisfaction.

It is clear that modelling teacher effort in just one dimension misses important aspects of what teachers do and how they take decisions about their teaching, i.e. how to provide a motivating and stimulating learning ambiance and how to foster the development of their intellectual and social skills. Although considering only pecuniary incentives and focusing on one generic task, we are well aware that other aspects are equally important but are to subject to a methodics and didactics, fields economics have little to contribute to.

3 Teacher Incentives

As discussed in the introduction, the literature discerns incentives systems which work within schools broadly into the two categories accountability and merit pay. While accountability systems per se provide an objective evaluation of teacher or student performance, they can be implemented directly by committing teachers or schools to certain student achievement levels – with or without explicit consequences for teachers or schools – or indirectly in the context of a merit pay scheme where verifiable standards serve as a proxy for teacher "merit" which can then be possibly contracted upon.

3.1 Accountability

By *accountability* we mean the establishment of some form of standards external to individual educational institutions and using tests to assure that teachers or entire schools are doing their best to meet the standards.

The problem of designing incentive compatible contracts is not unique to the situation in schools. Baker (1992) analyzes optimum contracts if an agent's payoff cannot be based on the principal's objective and proposes a statistical measure which serves as a metric for the efficiency of a performance measure. Prendergast (1999) reviews the literature on the provision of incentives in firms and concludes that agency theory indeed provides an important framework for understanding and designing compensation schemes. However, empirical evidence about their performance is largely missing. Lazear (2000) provides such evidence and extends the analysis of the impact of incentives on performance to their role in the determination and selection of the workforce. He finds that well designed monetary incentives (in a sector where effort is one-dimensional and well measurable) indeed attract more able workers and increase the output level and the variance in output across individuals.

Considering performance systems in public organizations, Heckman, Heinrich, and Smith (2002) examine the performance of the job training partnership act (JTPA) in 1993 as a prototype of a performance-standard incentive program. They find that performance standards in public service did not promote efficiency because the short-term outcomes they rely on had only little correlation with with long-run impacts on employment and earnings. Consequentially, also in that setting it has to be concluded that people respond to incentives, although perversely so if performance is only poorly measurable. The same conclusion is drawn by Koretz (2002) who reviews empirical evidence and discusses the logic of achievement tests in the U.S. His main argument is that tests exclude entire subject areas, leave many important goals of education unmeasured and elide attributes which schools are also supposed to foster, such as the interest in learning, and intellectual curiosity. Among the potential perverse effects of accountability are two forms of "coaching":

Reallocating achievement Teachers may emphasize certain subjects and reallocate instructional resources to focus more on content deemed important or particularly well testable.

Cheating Koretz (2002) reports about incidents in which educators told students which answers to change or gave them practice tests containing questions from operational tests.

On the basis of the general literature on incentive contracts and performance measurement, it is evident that a system of standards, accountability, and sanctions in schools must be well designed and well implemented in order to achieve some effectiveness. However, it is far from obvious how to design such a system, especially when differing political and other forces influence the design. One major problem is that standards in education may not be adequate for different classes: If there is exogenous heterogeneity, too low or too high standards which are too easily or not at all attainable may crowd out intrinsic motivation. Lazear and Rosen (1981) and Prendergast (1999) show that relative performance measures and rank-order tournaments are able to avoid problems associated with the level of standards. Kane and Staiger (2001) argue that accountability systems tend to over-reward and over-penalize small institutions which are likely to display unusually high or low performance, simply because noisy measures of students' achievement are less likely to average out. Systems with discrete cut-off levels tend to focus teacher effort on the students whose performance is just below a cut-off level. Therefore, Betts and Grogger (2000) suggest a relative performance hypothesis to explain how higher standards may reduce educational attainment (overall graduation rate) even as they increase educational achievement (test scores).

A potential problem of accountability measures is their narrowness: Jacob (2002) shows that gains in math and reading achievement due to an accountability policy in Chicago public schools in

1996-97 were largely driven by increases in test-specific skills and student effort. Teachers responded strategically to incentives, diverting effort from non-verifiable dimensions by increasing special education placements, preemptively retaining students and substituting away from low-stakes subjects like science and social studies.

Kane and Staiger (2002) argue that a test-based school accountability systems should exhibit three features that are currently lacking from most accountability systems in use: First, one should reward entire schools which have attained persistently high test scores over many years to increase the reliability of the performance estimate. Second, schools should be sorted into separate sized classes to account for the fact that smaller schools have more variable performance measures. An third, in order to preserve incentives in the short run, the optimal contract would reward schools for exceeding their expected performance, the size of incentive payments depending on the reliability of test scores measures.

The Dallas school accountability and incentive program which started in 1991 stands out from other incentive programs in the sophistication of its methodology for ranking schools (cf. Ladd, 1999). There, the full adjustment of individual test scores for the socioeconomic status of the students assures that the estimated value-added measures are not biased toward schools serving more advantaged children. In order to avoid narrow teaching to specific tests, the system relies on multiple measures of student outcomes, including two tests given annually, a criterion-referenced state test tied to the state curriculum and a nationally normed test. In addition, these tests are supplemented with a variety of other end-of-course tests and school-wide measures, such as student attendance and drop-out rates. In all cases, the measurement of student and school gains are measured relative to the average rather than some absolute value. Evaluating the program, Ladd (1999) concludes that there is a potential for it to have a positive impact on student outcomes. In seventh grade, results are consistently positive, though not for all ethnic groups alike. An other positive change is the fall in the Dallas drop-out rate relative to that in other cities. Hence, a well designed incentive program is at least potentially fruitful, albeit at high administrative and organizational costs. Consequently, states in the U.S. have lately moved away from developing teacher-specific incentive systems and toward group ratings and accountability (cf. Hanushek and Raymond (2004)).

In many countries, there is a system of school inspection using monitoring by on-site visits and expert judgement to identify schools with problems and applying pressure to improve performance. This is a flexible alternative to accountability based on tests; it avoids problems arising from imposing external demands on schools that are performing well, distorting teaching behavior and narrowing the range of curricular objectives. For example in England and Wales, since 1992, educational standards of public schools are assured and imposed through inspection by a government agency. The four objectives for these inspections named by the Office for Standards in Education are (1) raising standards of achievement by students, (2) enhancing the quality of educational experience enjoyed by pupils, (3) increasing the efficiency of the financial management of schools and (4) developing the ethos of the school (Ofsted, 1995).Ofsted (1995) In the model presented in section 3, we assume that monitoring allows the government to fully observe teacher effort at a positive social cost. This is the downside of on-site-visits compared to pure incentive contracts such as merit pay which comprise basically costless transfers only.[1]

[1]Rosenthal (2004) presents evidence that school inspections have an adverse effect on exam performance. However, inspections occur only once every four years or more, such that the reported results may be due to the inspections' inter-

3.2 Merit Pay

There are two broad approaches to providing monetary incentives to teachers for good performance:

Individual merit pay Merit pay which is assigned to individual teachers for their contribution to learning performance in a given time period, either based on an internal evaluation or more objective measures such as test results.

Group ratings Awards to whole school establishments in the form of a bonus divided between all members of the team involved in educational production.

In general, it seems very sensible to introduce monetary incentives to individuals. Lazear (2000) finds that in an auto glass company, productivity effects amounted to a 44 percent increase in output per worker once it shifted to piece rates. Lazear and Rosen (1981) show theoretically that also rank-order tournaments can induce the same efficient allocation of resources as a reward scheme based on individual output levels. Notwithstanding these encouraging studies, performance pay in educational institutions is very controversial. Hanushek (1994) and his co-authors are in favor of providing monetary incentives to individuals in education systems for good performance but recognize that there are difficulties, especially in changing from current systems to others based on strong incentives. They conclude that "in practice, designing a workable system of merit pay has proved elusive" (p. 95). The main problem in individual merit pay is that it relies on a too narrow band of incentives: a salary supplement and presumably status benefits. However, there are many different satisfactions to teachers of which monetary rewards are considered the least salient, such that they are not compelling to most teachers; thus, the reward offered is not particularly attractive. Glewwe, Ilias, and Kremer (2003) report on a program that provided primary school teachers in Kenya with incentives based on students' test scores. They find that students in program schools had indeed higher test scores during the time the program was in place, however, an examination of the channels through which this effect took place provides "little evidence that teachers responded to the program by steps to reduce dropouts or increasing effort on stimulating long-run learning" (p. 31). Eberts, Hollenbeck, and Stone (2002) review empirical evidence on the influence of merit pay schemes on student achievement across the U.S. Their results suggest that merit may indeed motivates teachers to produce outcomes which are directly rewarded – in their case increased student retention. However, there are also unintended results such as deteriorated average achievement due to the complex organization of schools with multiple teacher tasks, team production and multiple stakeholders. A very successful introduction of merit pay is evaluated by Lavy (2002, 2003, 2004) who finds that a rank-order tournament among teachers as a monetary performance incentive program in Israeli secondary schooling caused significant gains in many dimensions of students' educational achievement and that this programme is more cost-effective than alternative forms of intervention such as extra instruction time.

Lazear (2003) argues that observed positive effects of output-based pay may be due to a teacher sorting effect: Pay based on student achievement scores favors higher ability teachers relative to lower ability ones, where ability is defined in terms of the teacher's ability to raise achievement

action with more pressing and continuous influence on schools by annual puclication and public scrutiny of comparative exam and test scores.

scores. This effect may introduce a distortion in teacher hiring: If there are teachers who are good at raising test scores, but not at raising non-testable student performance, then pay based on test scores attracts those teachers who are capable at the former without getting those who excel on the latter.

Overall, it can be concluded that the concept of individual merit pay is theoretically very attractive while in practice the empirical evidence on its effectiveness is mixed. Potential problems with individual merit pay are: (1) that merit pay may interfere with schools' efforts to promote good teacher performance through pedagogical leadership, encouragement and steps to improve teacher morale; and (2) that it tends to introduce an adversarial atmosphere and create incentives to conceal problems.

A complement to individual merit pay in order to circumvent the above-mentioned problems may be the introduction of merit awards to whole schools. Ladd (1999) studies the experiment with school-based awards in Dallas and finds mixed evidence for a positive effect of such an incentive program on student performance. Awards to whole schools avoid many of the problems of individual merit pay, including the problem of damage to the institutional environment inside the school. However, it introduces the problem of free riding among teachers if social control within a school is weak.

4 Outline of the Model

Our model focuses on one-dimensional teacher effort and performance pay for individual teachers. The education process involves the sequence of events as displayed in figure 1.

1 Government sets teacher pay schedule, class size and monitoring;

2 Teacher chooses effort;

3 Nature resolves risk.

Figure 1

The sequence of decisions in the education model.

In the first stage, the government fixes its education policy which is fully characterized by prescribed class size, teacher remuneration schedule and possibly monitoring activities to learn about teacher effort. Subsequently, teachers decide on their effort which is – together with class size – a determinant of their students' success probability. In the third stage, nature resolves risk and the government pays teachers according to their wage schedule.

We assume the government to be benevolent, maximizing a simple utilitarian social welfare function over its budget constraint.

5 Educational Production

Educational production consists of providing students with a probability P to succeed. Student success as a result of educational production is a very abstract concept deserving detailed appraisal of its own. In the context of this paper we simply assume that schooling success is measurable as for example in external tests as discussed in section 3.1. Then, the passing of these tests may be either a prerequisite to move on to higher education or enable students to find highly qualified jobs. We are, however, well aware that such test are limited to only a few dimensions of educational outcomes. Hence, a comprehensive analysis would have to include an in-depth discussion of the very goals of education in schools (productivity, literacy, citizenship), and the multi-dimensionality of inputs in educational production (cf. e.g. Holmström and Milgrom, 1991 and Holmström, 1982). For the sake of simplicity and focus on the goal of this paper – to give a partial explanation of monitoring regimes at school – we abstract from these issues.

Success probability is a (positive linear) function of teacher effort and class size in the sense of Lazear (2001): When one student disrupts classwork, the entire class suffers; the teacher's and the other students' concentration is diverted from studying. Let π be the probability that a student is not misbehaving at any moment in time. Then, the probability that all students in a class of size m are behaving is π^m which is also equal to the proportion of schooling time during which students are effectively studying. Thus, the student success probability P is given by the following educational production function:

$$P = e\pi^m \qquad \pi \neq 1 \tag{1}$$

where e is teacher effort, m is class size, and π is the individual probability of non-disruption. Teachers incur a disutility from exerting teaching effort. They are risk neutral and have separable preferences over their wage T and their disutility of effort $U = T - \eta(e)$. The disutility of effort function $\eta(e)$ is increasing and convex in e with $\eta(0) = 0$. For simplicity, we assume an effort cost function of the form

$$\eta(e) = e^\gamma \qquad \gamma > 1,$$

with γ large enough to assure interior solutions. The teacher has an outside option of value $V = 0$ which forces the government to pay the teacher a transfer equal to her effort cost plus the value of her outside option V. In the following of the paper, we analyze the effect of two different government budget regimes on educational production: unlimited but costly resources and an exogenously fixed government budget.

5.1 Costly Government Resources

We start by assuming that the government disposes of unlimited but costly resources. Resource costs can be thought of as the excess burden of the taxation which is necessary to finance public education. Thus, the potential welfare effects of asymmetric information are not restricted to an inefficient allocation but include also the cost of financing teachers' information rents. For simplicity, we assume a constant cost $\lambda > 0$ per monetary unit.

5.1.1 Symmetric Information

As a benchmark case, we assume symmetric information. Thus, the government can observe and contract upon teacher effort. Given the teacher's outside option $V = 0$, the government solves the per-student problem (Π^*)

$$\Pi^* : \qquad W^* = \max_{e \in [0,1], m \in \mathbb{R}_+} P\overline{s} + (1-P)\underline{s} - \frac{1}{m}\eta(e)(1+\lambda). \tag{2}$$

In the government problem Π^*, $\bar{s}$ denotes the social value of a successful student, while $\underline{s}$ is the social value of an unsuccessful student. By the term *social value* we refer to a society's total benefit from an individual due to her education which consists of her wage and reputation as well as external benefits such as good citizenship or the enabling of others' productivity.[2]

To make the case of symmetric information valuable as a benchmark for the allocation under asymmetric information, we have to assume that the government cannot commit itself to its choice of teacher effort until class size has been fixed. Thus, P^* has to be solved backwards in order to obtain a time consistent solution. By the convexity of $\eta(e)$, the government's objective function is strictly concave in e, and direct optimization leads to the following first-order-condition defining the first-best level of effort under symmetric information:

$$m\pi^m \left(\bar{s} - \underline{s}\right) \stackrel{!}{=} \left(1 + \lambda\right) \eta' \left(e\right). \tag{3}$$

This is the Samuelson condition for the efficient provision of teacher effort in class which is a public good within a classroom by (1). It equates the total marginal benefit of teacher effort to marginal cost.

Optimization with respect to m yields

$$em\pi^m \ln \pi \left(\bar{s} - \underline{s}\right) + m\pi^m \left(\bar{s} - \underline{s}\right) \frac{\partial e}{\partial m} \stackrel{!}{=} -\frac{1}{m}\eta \left(e\right) \left(1 + \lambda\right) + \eta' \left(e\right) \left(1 + \lambda\right) \frac{\partial e}{\partial m}. \tag{4}$$

By the first-order-condition (3) defining e^*, the second term on the left hand side and the second term on the right hand side cancel each other. Again, the total marginal cost from increasing class size marginally must equal the marginal benefit consisting of lower effort cost per student. From (3) and (4) it follows directly that e^* and m^* are given by

$$e^* = \left[\frac{m\pi^m \left(\bar{s} - \underline{s}\right)}{\left(1 + \lambda\right) \gamma}\right]^{\frac{1}{\gamma - 1}} \tag{5}$$

and

$$m^* = -\frac{1}{\gamma \ln \pi}. \tag{6}$$

Figure 2 illustrates optimum teacher effort, total studying time in class, student success probability, and welfare in an example where the parameters are arbitrarily set to $\pi = 0.9$, $\gamma = 2$, $\bar{s} = 1$, $\underline{s} = 0$, $\lambda = 0.4$.

5.1.2 Asymmetric Information

In the case of asymmetric information, if teacher effort is not observable, the government has to take account of a teacher's incentive structure. Usually, in the context of a model with moral hazard, there is a rent extraction vs. efficiency trade-off faced by the principal. This is also the

[2]The evidence on external benefits from education is controversial: Acemoglu and Angrist (2001) find no external returns in the labor market while Lochner and Moretti (2001) report that individuals who obtain more education because laws prevent them from dropping out of school are less likely to commit a crime. Also, Dee (2003) finds that education has significant effects on subsequent voter participation, support for free speech and frequency of newspaper readership. This suggests that there might indeed be important nonmarket and social effects from education.

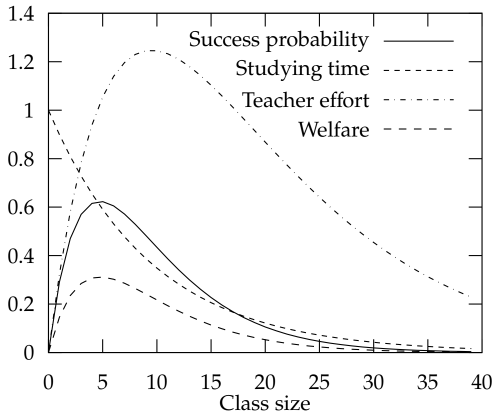

Figure 2

The first-best reactions of teacher effort, studying time and welfare on class size (illustration).

case here, but in an alleviated form: Since teacher rent is part of overall welfare, the government as principal has no a priori interest in rent extraction. However, because resources are costly, it minimizes expenditure in order to keep the social burden from sourcing small. The government induces effort by an incentive contract $(\underline{t}, \overline{t})$ per student where $\underline{t} = b$ is the teacher's base salary which she earns in case the student fails, and $\overline{t} = b + M \geq \underline{t}$ which contains an extra merit pay M if the student succeeds. Solving backwards, the risk-neutral teacher chooses effort e such that

$$e = \arg\max_{\tilde{e} \in [0,1]} mP\overline{t} + m(1-P)\underline{t} - \eta(\tilde{e}).$$

By the strict concavity of the teacher's objective function, the incentive constraint rewrites with the following necessary and sufficient first-order-condition:

$$IC: \qquad m\pi^m (\overline{t} - \underline{t}) = \eta'(e). \tag{7}$$

The teacher's participation constraint is given by the condition that the expected transfer minus her intangible effort costs at least balance the value of her outside option $V = 0$:

$$PC: \qquad mP\overline{t} + m(1-P)\underline{t} - \eta(e) \geq V. \tag{8}$$

Furthermore, we assume that teachers are protected by limited liability constraints which restrict government transfers to be non-negative in either state:

$$LLC_1 \quad : \qquad \underline{t} \geq 0; \tag{9}$$

$$LLC_2 \quad : \qquad \overline{t} \geq 0. \tag{10}$$

Without limited liability constraints, the government could still implement a first-best allocation – even in the case of asymmetric information with respect to teacher effort. However, this would imply a negative transfer in the case of the bad state, which is not a feasible policy option in terms of teacher remuneration.[3] When the first of these constraints is binding, the government is limited in its punishments in bad states. In order to maintain teacher incentives by the optimum wedge between $\overline{t}$ and $\underline{t}$, the government has to raise its transfers in the good state. As a result, the teacher

[3] For an in-depth discussion of limited liability constraits in a principal-agent setting see eg. Sappington (1983).

receives a non-negative ex ante limited liability rent described in result 1 below as a special form of information rent. The government's per-student problem is thus

$$\Pi^{SB} \quad : \qquad W^{SB} = \max_{\{(e,m,\bar{t},\underline{t})\}} P\bar{s} + (1-P)\,\underline{s} - \lambda\left(P\bar{t} + (1-P)\,\underline{t}\right) - \frac{1}{m}\eta\left(e\right) \tag{11}$$

subject to (7), (8), (9) and (10).

A preliminary result on $\left(\Pi^{SB}\right)$ is given in result 1.

Result 1 *With limited liability, only IC and LLC_1 are binding. Optimal transfers per student are given by*

$$\begin{aligned} \underline{t}^{SB} &= 0; \\ \bar{t}^{SB} &= \frac{\eta'\left(e\right)}{m\pi^m}. \end{aligned}$$

The teacher's expected limited liability rent is strictly positive: $e^{SB}\eta'\left(e^{SB}\right) - \eta\left(e^{SB}\right) > 0$.

Proof. The proof is given in appendix A.1. ■

Figure 3 displays a teacher's effort cost $\eta\left(e\right)$ and the total transfers $\overline{T} = mP\bar{t}^{SB} = e\eta'\left(e\right)$ by IC and $\underline{T} = 0$ by LLC_1.

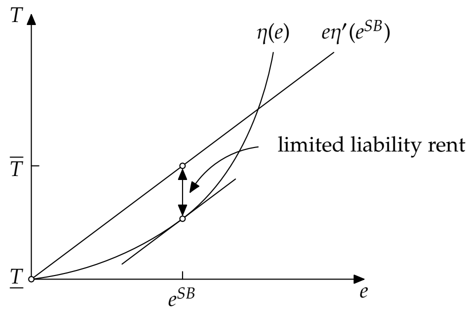

Figure 3

Teacher effort costs and the optimum transfer contract.

Replacing $\bar{t}^{SB}$ with $\frac{\eta'(e)}{m\pi^m}$ in the government's objective function, the reduced problem is written as

$$\Pi'^{SB}: \qquad W'^{SB} = \max_{e\in[0,1],m\in\mathbb{R}_+} P\bar{s} + (1-P)\,\underline{s} - \frac{\lambda}{m}e\eta'\left(e\right) - \frac{1}{m}\eta\left(e\right).$$

When $\eta''' > 0$ the government's objective function is strictly concave in e, and direct optimization leads again to the following first order conditions defining the second-best level of effort e^{SB} and m^{SB}:

$$m\pi^m\left(\bar{s} - \underline{s}\right) \overset{!}{=} \lambda e\eta''\left(e\right) + \eta'\left(e\right)\left(1+\lambda\right); \tag{12}$$

$$em\pi^m \ln\pi\left(\bar{s} - \underline{s}\right) \overset{!}{=} -\frac{1}{m}\left[\lambda e\eta'\left(e\right) + \eta\left(e\right)\right]. \tag{13}$$

Result 2 *In the second-best allocation, (a) teacher effort is inefficiently low, $e^{SB} < e^*$, while (b) classes are of efficient size: $m^{SB} = m^*$.*

Proof. The proof is given in appendix A.2. ■

The first-best effort is such that the marginal benefit $m\pi^m(\bar{s}-\underline{s})$ of increasing effort by a small amount de is just equal to the marginal disutility of doing so $(1+\lambda)\eta'(e^*)$. Under moral hazard, the marginal benefit $m\pi^m(\bar{s}-\underline{s})$ must be equal to the marginal cost $(1+\lambda)\eta'(e^{SB})$ plus the cost of the teacher's marginal limited liability rent $\lambda e^{SB}\eta''(e^{SB})$. Figure 4 shows optimum teacher effort, total studying time in class, student success probability, and welfare with the same parametrization as in figure 2.

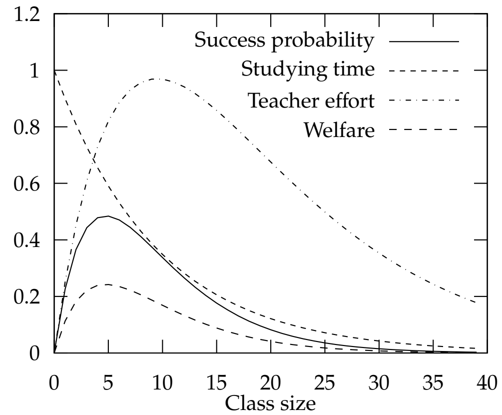

Figure 4

The second-best reactions of teacher effort, studying time and welfare on class size (illustration).

Note that – as indicated in result 2 – welfare is maximized at the same class size m^* as under symmetric information. However, teacher effort is unambiguously lower due to its non-observability.

5.1.3 Monitoring

In the case of symmetric information, no monitoring is needed to induce optimum teaching effort since it can be contracted due to its observability. Since asymmetric information with no binding limited liability constraint yields first-best results, no monitoring is needed then, either. If effort is not observable without monitoring and a limited liability constraint is binding, however, this may be a valuable alternative to induce optimum effort by incentive contracts. We assume that teacher effort e is observable and enforceable by the government if it employs monitoring. This means that the incentive constraint IC in the government problem no longer holds. The cost $\psi(e)$ of monitoring teacher effort is assumed to be linear in $\eta(e)$ with a factor of proportionality μ :

$$\phi(e) = \mu\eta(e) \qquad \mu \geq 0.$$

The government solves

$$\Pi_M'^{SB}: \qquad W_M'^{SB} = \max_{e\in[0,1],m\in\mathbb{R}_+} P\bar{s} + (1-P)\underline{s} - \frac{1}{m}\eta(e)(1+\lambda)(1+\mu).$$

Direct optimization leads to the following first order condition defining the second-best levels of effort and class size e_M^{SB} and m_M^{SB}:

$$m\pi^m(\bar{s}-\underline{s}) \stackrel{!}{=} \eta'(e)(1+\lambda)(1+\mu); \tag{14}$$

$$em\pi^m \ln\pi(\bar{s}-\underline{s}) \stackrel{!}{=} -\frac{1}{m}\eta(e)(1+\lambda)(1+\mu). \tag{15}$$

Result 3 *With hidden teacher effort, the following properties hold:*

$$(a) \quad e_M^{SB} \gtreqqless e^{SB} \iff \mu \lesseqqgtr \frac{\lambda}{1+\lambda}(\gamma - 1);$$
$$(b) \quad m_M^{SB} = m^{SB} \quad \forall \mu;$$

and teacher monitoring is the optimum government policy if

$$(c) \quad \mu < \frac{\lambda}{1+\lambda}(\gamma - 1). \tag{16}$$

Proof. The proof is given in appendix A.3. ■

To illustrate result (c) in result 3, consider what would happen if $\lambda = 0$. Then, the government does not care whether or not to concede a limited liability rent to the teacher since it's a costless transfer which does not change overall welfare. Thus, LLC_1 does not have to hold with equality anymore. Therefore, even under asymmetric information, the first-best allocation can be attained, which – in the case of monitoring – were only possible if $\mu = 0$. Choosing its optimum policy, the government compares the cost of a teacher's information rent $e^{\gamma}(\gamma - 1)\lambda$ to the cost of monitoring her effort $\mu e^{\gamma}(1+\lambda)$.

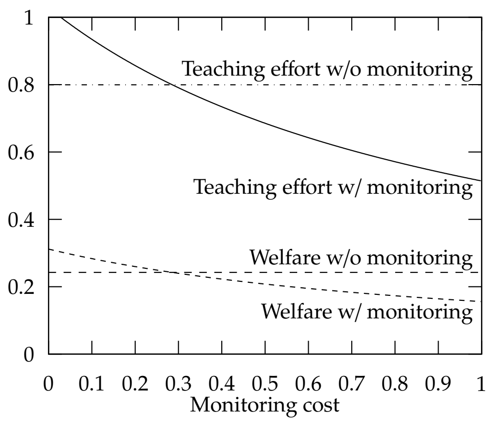

Figure 5

Teacher effort and welfare with and without monitoring (illustration).

Figure 5 illustrates the decision between monitoring and merit pay as a means of inducing optimum teacher effort. Both effort and welfare do not depend on monitoring cost μ if there is no monitoring. However, in case of monitoring, an optimizing government adjusts intended teacher effort according to μ due to its welfare implications. Hence, beneath a pivotal level of μ it is socially favorable to rely on monitoring. The concurrence of the intersection of the level of optimum effort and welfare under asymmetric information with their respective values in case of monitoring is due to the fact that optimum class size is not affected by asymmetric information which makes welfare directly dependent on teacher effort only.

5.1.4 Arbitrary Participation Constraint

So far, we have assumed a teacher outside option of value $V = 0$ which is never binding in the presence of a limited liability constraint. In this section, we generalize the participation constraint to any – possibly binding – value $V \in R$.

Symmetric Information Under symmetric information with an arbitrary teacher outside option V, P^* rewrites as

$$\Pi^* : \qquad W^{V*} = \max_{e \in [0,1], m \in \mathbb{R}_+} P\bar{s} + (1-P)\underline{s} - \frac{1}{m}\eta(e)(1+\lambda) - \frac{1}{m}\lambda V.$$

By the same line of argument as in section 5.1.1, optimum teacher effort and class size are given by

$$e^* = \left[\frac{m\pi^m(\bar{s}-\underline{s})}{(1+\lambda)\gamma}\right]^{\frac{1}{\gamma-1}}$$

and

$$m^* = -\frac{\lambda}{1+\lambda}\frac{V}{\gamma e^{\gamma}\ln\pi} - \frac{1}{\gamma\ln\pi}.$$

Note that optimum teacher effort depends on V only indirectly via class size.

Asymmetric Information Under asymmetric information, there are two mutually exclusive cases to be considered: In the first case LLC_1 is binding, in the second case PC is binding.

Result 4 *(a) With limited liability, only IC and LLC_1 are binding if $V < e\eta'(e) - \eta(e)$. Optimal transfers per student are given by*

$$\begin{aligned} \underline{t}^{SB} &= 0; \\ \bar{t}^{SB} &= \frac{\eta'(e)}{m\pi^m}. \end{aligned}$$

The teacher's expected limited liability rent is strictly positive: $e^{SB}\eta'\left(e^{SB}\right) - \eta\left(e^{SB}\right) > 0$.

(b) With limited liability, only IC and PC are binding if $V \geq e\eta'(e) - \eta(e)$. Optimal transfers per student are given by

$$\begin{aligned} \underline{t}^{SB} &= \frac{1}{m}V + \frac{1}{m}\eta(e) - \frac{1}{m}e\eta'(e); \\ \bar{t}^{SB} &= \underline{t}^{SB} + \frac{\eta'(e)}{m\pi^m}. \end{aligned}$$

The teacher's expected limited liability rent exceeding the value of her outside option is equal to zero.

Proof. The proof is given in appendix A.5. ■

Result 5 *(a) In the second-best allocation with a binding LLC_1,*
(a1) teacher effort is inefficiently low, $e^{SB} < e^*$, while
(a2) classes are inefficiently small iff there is a positive outside option to teachers: $m^{SB} < m^* \Longleftrightarrow V > 0$.
(b) If PC is binding, the first best allocation is achievable even under asymmetric information.

Proof. The proof is given in appendix A.6. ■

In the case of asymmetric information with a binding participation constraint, no monitoring is needed, since the limited liability rent is dissipated by the compensation of the teacher's outside option.

Monitoring Rule With $V \neq 0$ and if the limited liability constraint $LLC_1$is binding, there is no closed-form solution for the set of μ where monitoring is favorable to merit pay. An increase in V has the following effects: Without monitoring, welfare W'^{SB} remains constant as long as LLC_1 is binding since transfers are not affected by a changing V. In the case of monitoring, however, welfare $W'^{SB}_M = P^{SB}_M \overline{s} + \left(1 - P^{SB}_M\right) \underline{s} - \frac{1}{m^{SB}_M} \eta \left(e^{SB}_M\right) (1+\lambda)(1+\mu) - \frac{\lambda}{m^{SB}_M} V$ by the envelope theorem decreases by

$$\frac{dW'^{SB}_M}{dV} = -\frac{\lambda}{m} < 0.$$

Thus, the range of μ where monitoring outperforms merit pay decreases.

5.2 Fixed Government Resources

Contrary to the section above, we now assume that government expenditure is not costly, but fixed at a per-student-level g. The line of the argument remains basically the same, with the difference that optimum teacher effort e^* may not be attainable anymore due to lacking resources. We return to the assumption that $V = 0$. The government program is now

$$\Pi_\Gamma \quad : \quad W_\Gamma = \max_{e \in [0,1], m \in \mathbb{R}^+} P\overline{s} + (1-P)\underline{s} - c \qquad s.t.\ t \leq g \tag{17}$$

where c denotes the expected social cost:

$$c = \begin{cases} \frac{1}{m}\eta(e) & \text{no monitoring;} \\ \frac{1}{m}\eta(e)(1+\mu) & \text{monitoring.} \end{cases}$$

and t denotes the expected government transfer per student needed to obtain effort e:

$$t = \begin{cases} \frac{1}{m}\eta(e) & \text{symmetric information;} \\ \frac{1}{m}e\eta'(e) & \text{asymmetric information;} \\ \frac{1}{m}\eta(e)(1+\mu) & \text{asymmetric information, monitoring.} \end{cases} \tag{18}$$

The first-order conditions with respect to e and m are exactly the same as in the case of costly but unlimited government resources. With fixed resources, the third first-order-condition with respect to the Lagrangian multiplier λ has to be considered in addition. We will just state the results in this section and refer to appendix B for the calculations. With λ being the Lagrangian multiplier attached to the government budget constraint, optimum class size and teacher effort are given by equations (24) and (25) in the appendix. It can be checked easily that result 2 also holds with a fixed government budget. Once class size has been chosen, teacher effort is determined as well if the budget constraint is binding. According to (26) in the appendix, in the case of asymmetric information and extremely scarce resources, monitoring is socially preferable to teacher merit pay if

$$\mu < \gamma - 1. \tag{19}$$

The assumption of extremely scarce resources implies a high shadow price λ. Thus, in this case, the conditions (19) and (16) coincide. Compare (19) to (26) to see that the more government resources are available, the weaker the case for monitoring activity instead of incentive pay. Hence, an increase in the fixed government budget makes monitoring less attractive as indicated in figure 6 which displays μ that leaves the benevolent government indifferent between monitoring and merit pay – provided that the government's budget constraint is binding. When the budget constraint gets slack, there will be no monitoring since the first-best allocation can be attained anyway.

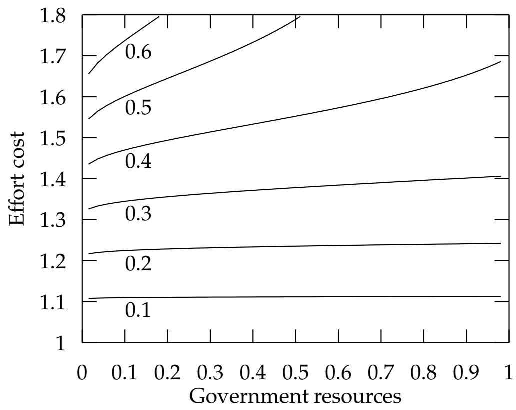

Figure 6

Pivotal values of μ in the regime choice problem (illustration).

With increasing government resources, the model exhibits local non-monotonicities in human capital production (see figure 7). This effect is due to the regime change from incentive contracts to monitoring as available government resources increase.

Result 6 *Assume $\mu < \gamma - 1$ and starting at $g = 0$, with growing value of g, there is a switch in the regime of optimum teacher incentives occurring at*

$$\tilde{g} = \left[-\frac{x_1}{x_2 \pi^m} \right]^{\frac{\gamma}{1-\gamma}}$$

with $x1 = \left(\frac{1}{\gamma^2 \ln \pi}\right)^{\frac{1}{\gamma}} - \left(\frac{1}{\gamma \ln \pi(1+\mu)}\right)^{\frac{1}{\gamma}}$, $x2 = \left(\frac{1}{\gamma^2 \ln \pi}\right) - \left(\frac{1}{\gamma \ln \pi(1+\mu)}\right)$.

Proof. The proof is given in appendix A.7. ■

The regime change may introduce multiple equilibria in a growth model where human capital is an argument in the final output production function. Consider for example a toy model where a fraction σ of the gross social benefit of education is re-invested in educational production. Then, in analogy to a simple neoclassical growth model, the differential equation of government expenditure can be written as

$$\dot{g} = \sigma \left(P\Delta s + \underline{s} \right) - g.$$

In such a setting, the non-monotonicity in the production of human capital leads – under certain parameter constellations – to multiple equilibria characterized by $\dot{g} = 0$. Such a situation is depicted in figure 8 where there are two stable equilibria:

$$g = \sigma \left(P\Delta s + \underline{s} \right).$$

Such effects in the production of an important factor of economic growth may help explain the lack of convergence established in the empirical literature (cf. Hall and Jones, 1999 and Barro and Sala-I-Martin, 2004).

This effect is similar to the one in Eicher and Penalosa (2003) who base their analysis on Murphy, Shleifer, and Vishny (1991) where multiple equilibria arise due to endogenous institutions.

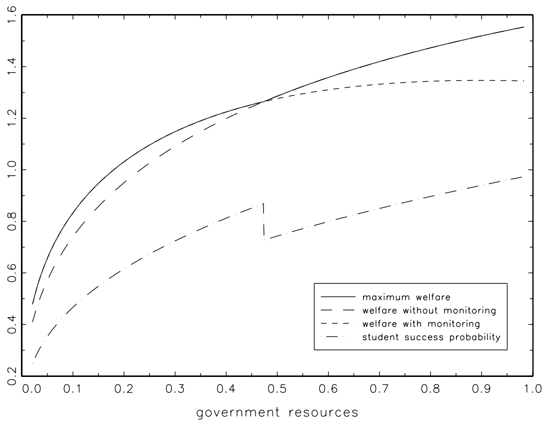

Figure 7

Pivotal values of μ in the regime choice problem (illustration).

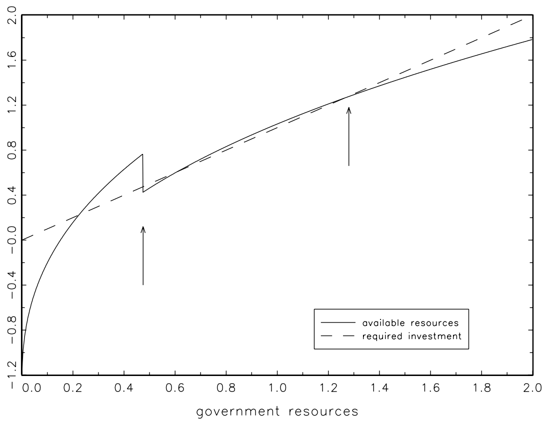

Figure 8

Stable equilibria in the growth process of government resources (illustration).

5.3 The Impact of Student Behavior

We have observed that optimum educational policy is directly affected by the disposition of the government's resources. In the same model setting, the impact of change in the student characteristics parameter π can be analyzed as well. The result is reported in result 7.

Result 7 *(a) Optimum class size is increasing in the probability π that students behave well. (b) Total studying time is constant in the probability π that students behave well. (c) Optimum teacher effort increases in the probability π that students behave well.*

Proof. The proof is given in appendix A.4. ■

Result 7 states that if π is observable, school authorities place better behaved students in larger classes. It implicitly assumes that it is optimal to segregate students according to their characteristic π in the first place. This is indeed the case in the present model as can be easily shown. For a proof of this result in a similar context, see Jaag (2005).

The result that class size is adjusted in response to student behavior impairs the possibility to find improved educational output when class size is reduced. Although more disruptive students are found in smaller classes, the effect of reducing class size is not sufficient to compensate their deficiencies. Hence, the congruity of common sense with the failure to find class size effects is restored once sorting effects are taken into consideration. Result 7 replicates propositions 1 and 2 in Lazear (2001) where teacher effort is kept constant over student characteristic π.

6 Conclusion

The model developed in this paper is very parsimonious. A more thorough modeling of the process of educational production which goes beyond the restriction of government and teachers as the two sole actors seems a promising direction for future research. E.g. students and their parents might be introduced as independent actors. Another extension of the model would be to include other educational resources than teacher effort or a more accurate description of teacher preferences.

While abstracting from these issues, the model presented in this paper is still capable of depicting the interaction between class size and teacher effort in educational production. The model shows that class size is adjusted in response to student behavior if the latter is publicly observable. This impairs the possibility to find improved educational output when class size is reduced. Although more disruptive students are found in smaller classes, the effect of reducing class size is not sufficient to compensate their deficiencies. Hence, the congruity of common sense with the failure to find class size effects is restored once sorting effects are taken into consideration.

The value of the teachers' outside option plays an important role in determining which policy is preferred: If it is such that the teacher's participation constraint is binding, there is no social cost from incentivizing teachers, thus no monitoring is ever required. If the participation constraint is slack, the teacher's limited liability constraint binds, thus introducing the possibility of a welfare increasing switch in policy. If government resources are available at a linear cost, monitoring is socially favorable as long as its costs lie below a certain threshold value which is a function of the convexity of teacher effort cost and government resource cost. If maximum government resources are fixed and the budget constraint is binding, then an increase in the fixed budget weakens the case for monitoring activity instead of incentive pay. Hence, an increase in the government budget makes monitoring less attractive. When the budget constraint gets slack, there will be no monitoring since the first-best allocation is attainable even under asymmetric information, thus rendering monitoring unnecessary.

The model allows to understand why incentive contracts are rarely employed in schools: If government resources are scarce, there is a social cost attached to incentivize teachers, such that other forms of stimulation may be more effective. More generally, a central implication of this paper is that institutional policies are potentially at least as important in guaranteeing a high quality in educational production than sole resource policies. From a macroeconomic perspective, the model may introduce multiple equilibria in growth settings, where human capital is an argument in the final output production function. Such effects in the production of an important factor of economic growth may help explain the lack of convergence established in the empirical literature (cf. eg. Hall and Jones, 1999).

Appendix

A Proofs

A.1 Proof to Result 1

We conjecture that (7) and (9) are the only relevant constraints. Both constraints are binding since government resources are only available at cost $\lambda > 0$. Hence, $\underline{t}^{SB} = 0$ and $\overline{t}^{SB} = \frac{\eta'(e)}{m\pi^m}$. We check that (10) is satisfied since $\frac{\eta'(e)}{m\pi^m} \geq 0$. We also check that (8) is satisfied by the convexity of $\eta(e)$, $\eta'(0) = 0$, and the fact that $e^{SB} > 0$. This also proves the positivity of the limited liability rent.

A.2 Proof to Result 2

Solve (12) for e to get

$$e^{SB} = \left[\frac{m\pi^m (\overline{s} - \underline{s})}{\gamma + \lambda\gamma^2}\right]^{\frac{1}{\gamma-1}}. \tag{20}$$

This solution is unique due to the concavity of P'^{SB} in e. Comparing (20) to (5) yields result (a) in the result. Check that (21) is a solution to (13). Since $\left.\frac{dW^{SB}}{dm}\right|_{m<m^{SB}} > 0$ and $\left.\frac{dW^{SB}}{dm}\right|_{m>m^{SB}} < 0$, m^{SB} must be the unique solution:

$$m^{SB} = -\frac{1}{\gamma \ln \pi}. \tag{21}$$

Comparing (21) to (6) yields result (b) in the result.

A.3 Proof to Result 3

Solve (14) for e to get

$$e_M^{SB} = \left[\frac{m\pi^m (\overline{s} - \underline{s})}{\gamma (1+\lambda)(1+\mu)}\right]^{\frac{1}{\gamma-1}}. \tag{22}$$

Comparing (22) to (20) yields the equality in result (a) of the result. Since $\left.\frac{de_M^{SB}}{d\mu}\right|_{m=m_M^{SB}} < 0$ and $\left.\frac{de^{SB}}{d\mu}\right|_{m=m^{SB}} = 0$ also the inequalities hold. Check that (23) is a solution to (15). Since $\left.\frac{dW_M^{SB}}{dm}\right|_{m<m_M^{SB}} > 0$ and $\left.\frac{dW_M^{SB}}{dm}\right|_{m>m_M^{SB}} < 0$, m_M^{SB} must be the unique solution:

$$m_M^{SB} = -\frac{1}{\gamma \ln \pi}. \tag{23}$$

Comparing (15) to (21) yields result (b) in the result. Result (c) holds by (a) and (b) and the fact that the cost terms in (P'^{SB}) and $(P_M'^{SB})$ coincide iff $\mu = \lambda\frac{\gamma-1}{1+\lambda}$.

A.4 Proof to Result 7

(a) Differentiate m^* with respect to π to find $\frac{\partial m^*}{\partial \pi} = \frac{1}{\pi\gamma(\ln \pi)^2} < 0$. (b) Studying time is given by π^m. Differentiate with respect to π to get $\frac{\partial \pi^m}{\partial \pi} = 0$. (c) Substitute m^* into (5), (20), or (22) and differentiate with respect to π to get the result.

A.5 Proof to Result 4

(a) We conjecture that (7) and (9) are the only relevant constraints. Both constraints are binding since government resources are only available at cost $\lambda > 0$. Hence, $\underline{t}^{SB} = 0$ and $\overline{t}^{SB} = \frac{\eta'(e)}{m\pi^m}$. We check that (10) is satisfied since $\frac{\eta'(e)}{m\pi^m} \geq 0$. We also check that (8) is satisfied since by the condition $V < e\eta'(e) - \eta(e)$. This also proves the positivity of the limited liability rent.

(b) We conjecture that (7) and (8) are the only relevant constraints. Both constraints are binding since government resources are only available at cost $\lambda > 0$. Hence, $\underline{t}^{SB} = \frac{1}{m}V + \frac{1}{m}\eta(e) - \frac{1}{m}e\eta'(e)$ and $\overline{t}^{SB} = \underline{t}^{SB} + \frac{\eta'(e)}{m\pi^m}$. We check that (9) is satisfied by the condition $V \geq e\eta'(e) - \eta(e)$. We also check that (10) is satisfied since $\frac{\eta'(e)}{m\pi^m} \geq 0$. The expected excess limited liability rent is given by $P\underline{t}^{SB} + (1-P)\,\underline{t}^{SB} - V - \eta(e) = 0$.

A.6 Proof to Result 5

(a) Solve (12) for e to get

$$e^{SB} = \left[\frac{m\pi^m(\overline{s} - \underline{s})}{\gamma + \lambda\gamma^2}\right]^{\frac{1}{\gamma-1}}.$$

Comparing (20) to (5) yields result (a1) in the result. Check that (21) is a solution to (13). Since $\left.\frac{dW^{SB}}{dm}\right|_{m<m^{SB}} > 0$ and $\left.\frac{dW^{SB}}{dm}\right|_{m>m^{SB}} < 0$, m^{SB} must be the unique solution:

$$m^{SB} = -\frac{1}{\gamma \ln \pi}.$$

Comparing (21) to (6) yields result (a2) in the result.

(b) Replacing $\overline{t}^{SB}$ and $\underline{t}^{SB}$ in the government's objective function and exploiting the first-order conditions yields the same optimum levels of e and m as with symmetric information.

A.7 Proof to Result

By insertion, note that $\widetilde{g}$ satisfies $W_\Gamma^{SB} = W_{\Gamma,M}^{SB}$ with $W_\Gamma^{SB} = P\overline{s} + (1-P)\,\underline{s} - \frac{1}{m_\Gamma^{SB}}\eta\left(e_\Gamma^{SB}\right)$ and $W_{\Gamma,M}^{SB} = P\overline{s} + (1-P)\,\underline{s} - \frac{1}{m_{\Gamma,M}^{SB}}\eta\left(e_{\Gamma,M}^{SB}\right)(1+\mu)$. This proves the existence of a change in the regime. Note also that $\left.W_\Gamma^{SB}\right|_{g=0} > \left.W_{\Gamma,M}^{SB}\right|_{g=0}$ and $\frac{d}{dg}\left(W_\Gamma^{SB}\right) > \frac{d}{dg}\left(W_{\Gamma,M}^{SB}\right)$. Once g has reached a value such that the government budget constraint is no longer binding, there will be no monitoring anyway. Thus, $\widetilde{g}$ is the only value of g satisfying $W_\Gamma^{SB} = W_{\Gamma,M}^{SB}$.

B Fixed Government Resources

With fixed government resources, there are basically two cases to be considered, in both scenarios of symmetric information and hidden effort. In the first case, the budget constraint is slack, which implies that government resources are free. This result corresponds to the one in section 5.1.2 with $\lambda = 0$. The budget constraint is slack if

$$g > \begin{cases} \frac{1}{m^*}\left[\frac{m^*\pi^{m^*}(\bar{s}-\underline{s})}{\gamma}\right]^{\frac{\gamma}{\gamma-1}} & \text{with symmetric information;} \\ \frac{\gamma}{m^{SB}}\left[\frac{m^{SB}\pi^{m^{SB}}(\bar{s}-\underline{s})}{\gamma}\right]^{\frac{\gamma}{\gamma-1}} & \text{with asymmetric information.} \end{cases}$$

Since in this case the first-best allocation is attainable even under asymmetric information, there will never be wasteful monitoring (see result 3). In the second case, the budget constraint is binding. This is what we assume in the following. Thus, the government program is given by equations (17)-(18).

Symmetric information With symmetric information, exploiting the first-order conditions

$$\begin{aligned} e\pi^m \ln \pi \left(\bar{s}-\underline{s}\right) &= -\frac{1+\lambda}{m^2}\eta\left(e\right); \\ \pi^m \left(\bar{s}-\underline{s}\right) &= \frac{1+\lambda}{m}\eta'\left(e\right) \end{aligned}$$

and the budget constraint yields

$$\begin{aligned} m^*_\Gamma &= -\frac{1}{\gamma \ln \pi}; \\ e^*_\Gamma &= \left[-\frac{g}{\gamma \ln \pi}\right]^{\frac{1}{\gamma}}. \end{aligned}$$

Asymmetric information with a binding participation constraint In the case of unobservable teacher effort, if the government undertakes no monitoring and if PC is binding, the first-best allocation results since by result 4, LLC_1 is not binding. No monitoring will be needed to induce optimum teacher effort.

Asymmetric information with a binding limited liability constraint In the case of unobservable teacher effort, if the government undertakes no monitoring and if LLC_1 is binding, analogous calculations yield

$$\begin{aligned} m^{SB}_\Gamma &= -\frac{1}{\gamma \ln \pi}; \\ e^{SB}_\Gamma &= \left[-\frac{g}{\gamma^2 \ln \pi}\right]^{\frac{1}{\gamma}}. \end{aligned}$$

By result 5, PC is not binding in this case, thus V does not enter the optimization problem. Note that with $V = 0$, optimum class size is not affected by the non-observability of teacher effort. This is due to the fact that decreasing class size is costless per se; it burdens the budget only via its interaction with teacher effort.

Asymmetric information with monitoring In the case of asymmetric information with monitoring, the respective optimum values of m and e are given by

$$m_{\Gamma,M}^{SB} = -\frac{1}{\gamma \ln \pi}; \tag{24}$$

$$e_{\Gamma,M}^{SB} = \left[-\frac{g}{\gamma \ln \pi (1+\mu)}\right]^{\frac{1}{\gamma}}. \tag{25}$$

Monitoring condition Compare $W_{\Gamma}^{SB} = P\overline{s} + (1-P)\underline{s} - \frac{1}{m_{\Gamma}^{SB}}\eta\left(e_{\Gamma}^{SB}\right)$ and $W_{\Gamma,M}^{SB} = P\overline{s} + (1-P)\underline{s} - \frac{1}{m_{\Gamma,M}^{SB}}\eta\left(e_{\Gamma,M}^{SB}\right)(1+\mu)$ to find that, in the case of asymmetric information with a binding limited liability constraint, monitoring is socially preferable to teacher merit pay if

$$\mu < \left[\frac{\left(-\frac{g}{\gamma^2 \ln \pi}\right)^{\frac{1}{\gamma}} \pi^{\left(-\frac{1}{\gamma \ln \pi}\right)} \Delta s - \frac{g}{\gamma} - g}{\left(-\frac{g}{\gamma \ln \pi}\right)^{\frac{1}{\gamma}} \pi^{\left(-\frac{1}{\gamma \ln \pi}\right)} \Delta s}\right]^{-\gamma} - 1 \tag{26}$$

where $\Delta s = \overline{s} - \underline{s}$. Let $g \longrightarrow 0$, thus making government resources extremely scarce resulting in the shadow price $\lambda \longrightarrow \infty$. Then, (26) writes as

$$\mu < \gamma - 1$$

which is the condition stated in (19).

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